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"Biodiesel Production: a solar and windpower energy management and integration system model"

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Abstract

Biodiesel production, especially in its social revenue improvement and regional development of public policies forms – such as the Brazilian “PNBP” (National Program for Biodiesel Production) –, presents a high level of technological and business management demands, concerning integrated factors such as productivity, environmental and social impacts and technical viability.

From the public policy management perspective, there are great demands on the analysis of the governance of production systems, regarding production measured against costs, depending on raw material resources, land use and specially the energy costs role for the production chain.

This article reviews those production costs, in order to demonstrate that energy managements, as part of the technology management decision-making, may be a very important factor concerning the reduction of production costs, by integrating wind power and solar energy.

Renewable energy use for agricultural production can be more efficient for biodiesel production – from the environmental, economic and social perspectives – when looking to the diverse production ensemble (land use, raw material resources, etc.).

Wind power and solar energy for agro-industry production seem to be able to overturn part of the negative factors of production costs of biofuels, especially for biodiesel, reducing the current production costs of PNPB.

In this context, this paper presents:

1. The biodiesel agro-industrial chain and technological drivers and bottlenecks;
2. The review of the main goals of PNPB and implementation procedures;
3. Wind power and solar energy availability for biodiesel production, on the field of PNBP.

Keywords: technology management; energy management; biofuels; public policy; regional development.

1. Introduction

In the ‘80s, seeking renewable alternatives to replace oil, biodiesel returns to the energy scenario of the time, as a leading candidate to substitute diesel. At this same time, the federal government created the PRO-OIL – Plan for the Production of vegetable oils for fuel purposes. However, with the fall in oil prices in 1986, the plan was abandoned, but, notwithstanding, Brazilian research studies on biodiesel continued.

From the 90s, for several reasons, including political and economic ones, besides the awareness on the environmental problems posed by fossil fuels, biodiesel becomes an alternative energy source, as several studies show that it reduces the emission of greenhouse gases.

At the end of the twentieth century, biodiesel returns to the Brazilian government agenda, which forms partnerships with research centers and universities. In October 2002, the Ministry of Science and Technology created PROBIODIESEL, which was intended to replace by 2005 all diesel consumed by B5, and, up to 15 years, by B20[1].

In 2003, through a presidential decree[2], an interministerial work team was created to study the feasibility of using oils, fats and derivatives as fuel. This group considered that biodiesel should be immediately inserted in the energy matrix of the country; however, they pointed out that its use should not be mandatory, there should not be a preferred technology or raw material for its production, and also that the socio-economic development of regions and poor populations should be taken into account.

After a year, the National Program for Biodiesel Production and Use (PNPB) was then launched, whose main objective is to ensure an economically viable production of biofuels

[1] B5 = 5% of biodiesel + 95% of diesel; B20 = 20% of biodiesel + 80% of diesel.
[2] Presidential Decree of July 2, 2003.

and to contribute to the generation of regional income and social inclusion. The PNPB is based on the production of biodiesel in different regions of the country from the use of different sources of oil.

In 2004, the Ministry of Science and Technology created and organized the Brazilian Network of Biodiesel Technology (RBTB), in order to articulate the various agents involved in the research and production of biodiesel to identify and eliminate technological bottlenecks in the area.

Law No. 11.097/05 introduced biodiesel in Brazil's energy matrix, making it mandatory the blend of 2% of this fuel in the diesel sold to final consumers since January 2008 and 5% from January 2013 (BRASIL, 2005). The tax burden of biodiesel, by Law No. 11.116/05, can be adjusted by the Executive, with the proviso that it does not go beyond than that of mineral diesel, confirming the principles of PNPB of renewing the Brazil's energy matrix in line with minimizing social inequality (CARVALHO *et al*., 2007).

Biodiesel is a direct substitution of diesel and can be used directly in diesel combustion engines without any modification. Therefore, its adoption does not result in additional costs of adaptation, as in the case of alcohol, which requires flex-fuel engines.

The social aspect of the sustainable development is covered in PNPB through increased rural income and social inclusion. The Northeast region of the country stands out for its ability for agricultural expansion and environmental conditions favorable for the cultivation of oilseeds (castor bean as the main one).

The PNPB also focuses on family farming and producers of the poorest regions of Brazil. PRONAF Biodiesel was created for the development of family farming in the production of biodiesel, which allows the farmer to obtain another credit before payment of the previous one for the planting of oilseed (CARVALHO *et al*., 2007). The Social Fuel Seal is awarded to the biodiesel producer that purchases from these farmers the inputs, enabling benefits with the country's financing programs (banks BNDES[3], BASA[4], BNB[5] and Banco do Brasil[6]). This seal is governed by criteria and procedures established by the Ministry of Agrarian Development, from the obtaining, maintenance, renewal, suspension up to the cancellation of this certification (CARVALHO *et al*., 2007).

The PNPB, since its inception, has achieved some milestones: 27 industrial plants for the production of biodiesel came into existence (unofficial data); 13 pilot plants are in operation; the first biodiesel plant with animal fat was inaugurated in 2007 in the city of Lins, state of São Paulo; in 2007 there were 100,000 family farmers producing raw materials for biodiesel production; and financial transactions was close to R$ 120 million (MATTEI, 2009).

2. Bottlenecks in the production of biodiesel in Brazil and the Northeast:

To understand the setting of the biodiesel production in Brazil and in the Northeast, it is necessary that we first have an overview of the supply chain and all its activities, sectors and players, as shown below:

[3] BNDES: Banco Nacional de Desenvolvimento Econômico e Social (National Bak for Economic and Social Development)
[4] BASA: Banco da Amazônia (Amazon Bank)
[5] BNB: Banco do Nordeste do Brasil (Bank of Northeastern Brazil)
[6] Banco do Brasil (Bank of Brazil)

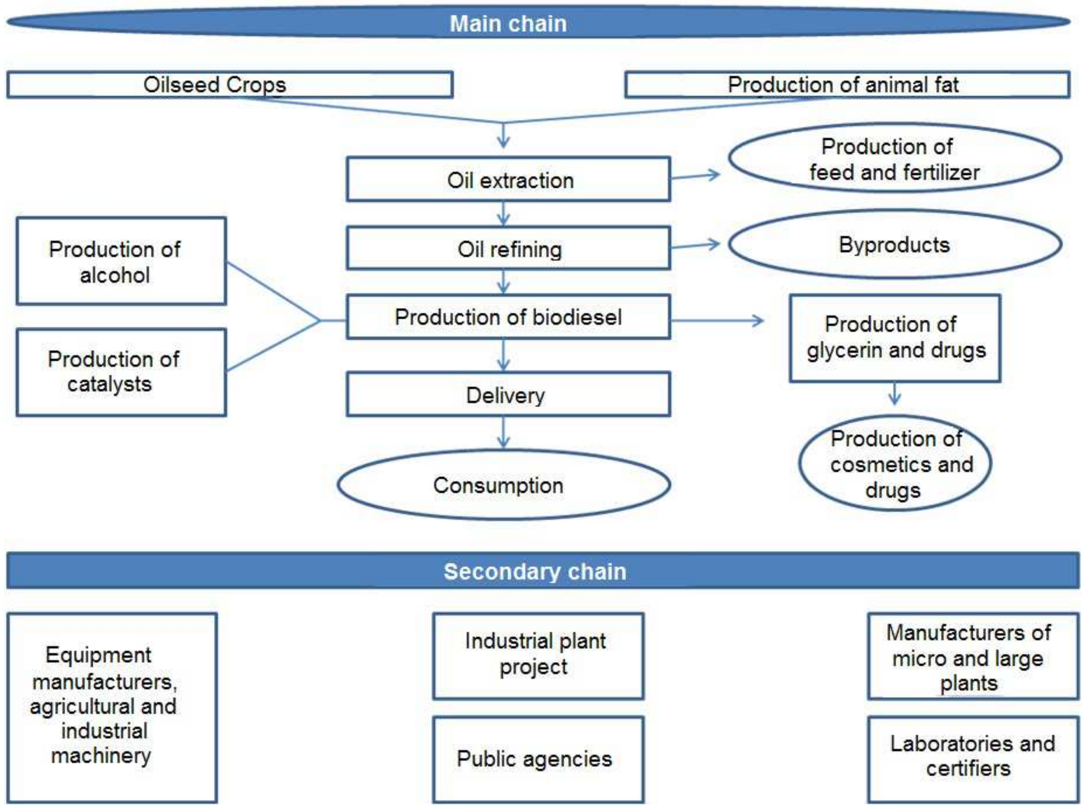

Figure 1. Illustration of the biodiesel production chain.
Source: CARMO *et al*. Análise do impacto nos custos de transporte de um modelo de seleção de fornecedores baseado em variáveis socioambientais e de competitividade. Mar 04, 2011.

In 2004, when PNBP was created, it was positively evaluated, as it tried to include family farming in its supply chain. This choice was seen as one of the major outlets for small farmers in the semi-arid northeast, but the raw materials dictated by PNPB (mainly castor bean) have prevented the participation of family farming in this chain.

The main oilseeds potentially usable in the production of biodiesel in the Brazilian scenario are: soybean, cotton, palm, sunflower, peanut, jatropha and castor bean. The castor bean was selected because its high content of vegetable oil, requires few nutrients and is drought resistant, that is why it was defended as a good choice for small farmers. However, the experiments showed no satisfactory results, obtaining lower yields per area and high prices that ultimately made unfeasible the cultivation of castor bean for the purposes intended by PNPB. As part of the solution, it is being studied the replacement of castor bean by jatropha or palm, oilseeds with good features to be applied to family farming, as shown in the table below.

Table 1. Characteristics and productivity of oilseed crops in Brazil.

SPECIES	SOURCE OF THE OIL	OIL CONTENT (%)	HARVEST MONTHS/YEAR	YIELD (OIL TON/HA)
Palm	Nut	22	12	3.0 – 6.0
Coconut	Fruit	55 – 60	12	1.3 – 1.9
Babassu	Nut	66	12	0.1 – 0.3
Sunflower	Bean	38 – 48	3	0.5 – 1.9
Colza/Canola	Bean	40 – 48	3	0.5 – 0.9
Castor	Bean	45 – 50	3	0.5 – 0.9
Peanut	Bean	40 – 43	3	0.6 – 0.8
Soybean	Bean	18	3	0.2 – 0.4
Cotton	Bean	15	3	0.1 – 0.2

Source: Paulillo *et al*. (2006).

To understand what impacts a replacement crop has for the production of raw materials for small farmers from the semi-arid Northeast, first we need to identify the problems associated with the use of castor bean. From the problems identified, we can relate: soil preparation, such as the lack of the presence of limestone; the use of heavy machinery, causing soil compaction, which makes it difficult for the castor bean to fix its deepest roots; the lack of knowledge about sowing methods, such as rotation of crops. These gaps greatly lower the productivity of castor oil in the region.

These issues are of great importance for the success of PNPB and for the inclusion of small farmers in the program. The lack of good farming practices by small farmers is very common in most of the crops to be grown, each with advantages and disadvantages, as shown in the table below:

Table 2. Characteristics and productivity of oilseed crops in Brazil.

RAW MATERIAL	**ADVANTAGES**	**DISADVANTAGES**
SOYBEAN	- Production chain already structured and Brazilian export; - Rapid return on investment; - There is already a specific research structure; - Cultivation adapted to various areas of the country; - Possibility of storing the grain for a long time; - Low cost of production.	- The price of the bean in international demand tends to make unfeasible its use as biofuel; - The varieties produced in Brazil have low oil content and yield (ton of oil/ha); - The soybean production chain is patronal, therefore does not include family farming, the focus of PNPB.
COTTON	- Traditional culture of the Northeast; - Can be grown in large and small properties; - It can be intercropped with other crops; - Nontoxic (can be used as animal feed); - The cotton lint can also be commercialized.	- Low productivity rates (oil content and ton of oil / ha).
JATROPHA	- High oil content (50%); - High productivity; - Perennial plant; - Adaptable to the soil and climatic conditions of the semi-arid Northeast.	- Insufficient research to confirm the exact production cycle; - Insufficient research to indicate the actual efficiency; - Insufficient research to indicate the degree of susceptibility to diseases and pests.
PALM	- Oil content similar to soybean; - Intensive harvesting tends to generate employment and income; - Best yield index (ton of oil / ha).	- Low average productivity (20000 kg/ha); - Long period of return on investment; - High perishability of the product; - Biodiesel from this raw material solidifies at lower temperatures (1); - It does not always provide satisfactory income, especially given the low productivity of the semi-extractive and extractive crops (2).

SUNFLOWE R	- Good economic prospects.	- Requires minimum precipitation water (an obstacle in the semi-arid Northeast); - Little-known culture by local farmers.

Source: Our own elaboration.

Even though palm is the most productive crop (in ton of oil / ha), the production of biodiesel in Brazil tends to use soybean oil, primarily because of its abundance and the presence of an already structured supply chain, able to support the growing demand in the sector.

We can observe a set of obstacles that are responsible for the insignificant share of family farming in PNPB. Even when ensuring the production coming from family farming, this does not mean that there is a vertical integration, and that major producers restrict the participation of the family farm. One of the solutions found by the Federal Government was the installation of community units for the extraction of vegetable oil (GONÇALVES, 2008), providing added value to these family farm communities, managed into cooperatives by the producers themselves.

The bottlenecks in the biodiesel supply chain are not limited to family farming, but include other players. There are still many conflicts involving the biodiesel issue: auctions, access to credit via PRONAF, other requirements from PNPB itself and the social seal. The competitiveness of biodiesel in Brazil also stumbles in the high production costs, as the technology for the processing is still not enough.

As highlighted by SECOM (2011), PNPB has agricultural, marketing and management bottlenecks.

Among the various bottlenecks we can highlight that the small producer does not have as many financial resources as the big ones to invest in the necessary minimum items required by PNPB. One of the solutions for this problem is the formation of cooperatives, in which small producers, together, are stronger in order to reach the level of the big producers, and also to have bargaining power. Even the Ministry of Agrarian Development supports the formation of cooperatives, in order to overcome this bottleneck.

The raw material widely exploited by producers is still soybean, but it has the lowest yield per hectare, 480 kg of oil / ha. The palm[7] is the raw material that holds the highest productivity per hectare, reaching 5,000 kg of oil/ha. Castor bean, in turn, despite being the second largest source of biodiesel, will not have a long future because, as argued by Dabdoub (2005), in the first studies that were done, it is shown that the diesel resulting from castor bean is very viscous and has density problems, being far less competitive than biodiesel from other sources.

Although the supply of the installed production capacity of biodiesel is higher than the national demand, biodiesel production has not met the volume required in the country. This is due mainly to the technological and managerial bottlenecks, as there are losses, idle capacity and poor management of resources along the production chain of biofuels. The offer of the production of castor in 2008 was insufficient to meet the demand of the Northeast, exactly because the system has a high demand for management, particularly for technology. In the case of lack of biodiesel produced in Brazil, PETROBRAS is required to import the product to meet the minimum percentage established by law. The main bottlenecks for the production of biodiesel in Brazil and in the Northeast are:

[7] *Opuntia cochenillifera.*

- Organization of production activities of oilseeds;
- Privileged logistics corridor – geographical distances for biodiesel production plants, working railways and roads;
- Storage infrastructure;
- Technical assistance and rural extension services;
- Incentive in prices;
- Management of extraction units by family farmers – management capacity and cooperative vision;
- Operation 300 days a year – unlikely in the reality of family farming;
- The minimum production of biodiesel added to diesel requires 60 million hectares of castor bean – short of demand;
- In 2007, the predominant raw material in the production of biodiesel was soybean;
- Low productivity;
- Deficiency in the production chain - cooperatives, production of improved seeds;
- Oil with higher density and viscosity;
- The toxicity of castor bean prevents its use in animal feed;
- The cost of the raw material is higher than the liter of oil;
- The quality of natural resources in different regions influences the production systems;
- Oilseeds require ongoing efforts to increase productivity and for the integration of technological innovations (far away from the activities that would guide the family farm);
- Family farming is generally based on the production of different crops;
- The integrators guide producers for the intercropped production (infeasible for the Semi-Arid);

- The family farm produces most of the food in the Semi-Arid (CARVALHO *et al*., 2007);
- High subsidies and tariff barriers applied by developed countries on imports of agricultural products;
- In 2007: through auction for the purchase of biodiesel, the supply of companies was 30% smaller than the quantities traded;
- Part of the volume traded was produced outside the norms established by the ANP (the Brazilian National Petroleum Agency) in 2007 (MATTEI, 2009).

Currently, all discussions about biodiesel have sought to prioritize oilseeds that may, in addition to producing fuel, provide more employment and labor, being thus inserted in regions that are in the process of economic growth. However, we should observe that that the sustainability of biofuels, whose changes in environmental indicators, such as the care for water resources, preservation of areas and conscious allocation of solid waste will have to be taken into consideration for an environmentally conscious progress of the concept and not only the social.

These conditions determine economic variables - such as, for example, the opportunity cost, productivity and prices, social advantages of family farming and environmental advantages of biodiesel.

3. Availability and feasibility of using wind and solar energy in agroindustrial production of a biofuel.

The feasibility of using wind and solar power in the agribusiness production chain mainly depends on the competitiveness of these energy sources in relation to the alternatives available in the market, both renewable and nonrenewable. The adoption of these renewable energies in rural areas can be achieved by buying at auctions, distributed in the National Interconnected System (SIN), or by investing in owing photovoltaic panels and wind turbines, or in partnership.

3.1 Production costs of wind and solar power:

Although wind power represents only 0.5% of the domestic supply of electricity in the country, according to data from the 2012 National Energy Balance, and the supply of solar energy is negligible, the combined supply of these renewable energy have more than doubled from 2002 - 2011 (offer fully absorbed by the market).

The increase in the supply of solar and wind energy in SIN is due to new investment, driven by the increasing competitiveness of such energy sources as well as by government programs (Program to Encourage Alternative Sources of Energy – PROINFA, for example).

In a study conducted by the OECD (2010), entitled "Projected Costs of Generating Electricity", the main cost related to these energy sources is the cost entailed by the still low and variable load factor, power or capacity used, of the generating units: between 21% and 41% for onshore wind energy, 34% and 43% for offshore wind energy and 10% and 25% for solar energy, in OECD countries.

The average costs for wind power generation were (they are not included in the calculation costs of expanding transmission lines): a discount rate of 5%, between 48 USD/MWh (United States) and 163 USD/MWh (Switzerland) for onshore, and 101 USD/MWh (United States) and 188 USD/MWh (Belgium) for offshore; in a discount rate of 10%, between 70 USD/MWh (United States) and more than 234 USD/MWh (Switzerland) for onshore, and 146 USD/MWh (United States) and 261 USD/MWh (Belgium) for offshore.

However, the study shows that these values mainly serve to identify trends, and not to perform accurate simulations. The 2010 edition includes, for the first, onshore wind energy among the sources of potentially competitive electricity generation. The greatest weakness of wind energy appointed by the report is its variability and unpredictability, which can be countered by the geographical diversity of the generating units. Finally, it concludes that wind energy is in a relatively competitive level; its price competitiveness depends mainly on regional characteristics: wind energy potential, financial costs and prices of fossil fuels.

The price of wind power for the domestic market could be even lower than the results reported by OECD countries, since the potential and intensity of winds in Brazil are greater. Wind energy also has the advantage of complementarity with the hydroelectric or biomass systems, predominant in the Brazilian scenario, since, in many parts of the country, the winds are stronger and more constant precisely in times of drought in the reservoirs and in the off season of crops whose residues can be used in power generation (ORTIZ, 2005).

In fact, a recent auction held by the Brazilian Electricity Regulatory Agency (ANEEL) included projects that offered prices between R$ 87.50 and R$ 89.20, although these prices have been greeted with skepticism by some industry representatives (O POVO, 2012).

For solar energy, average costs, assuming a load factor of 25%, were 215 USD/MWh (5% discount) and 333 USD/MWh (10% discount). For a load factor of 10%, costs were approximately 600 USD/MWh. For Eurelectric and the U.S. Department of Energy, the average costs of their plants were approximately 136 USD/MWh and 243 USD/MWh for discount rates of 5% and 10%, respectively (OECD, 2010).

Although the cost of solar energy (according to the OECD) are still very high, Pearce (2011) argues that the estimates made by most methodologies are very conservative, as it does not take into account the technological variety of photovoltaic panels on the market, among other factors.

In an interview (QUEENS UNIVERSITY NEWS, 2011), Pearce notes that some studies do not consider the 70% reduction in the cost of the panels, which occurred in 2009. Manufacturing costs of the panels have been falling rapidly due to economies of scale, while other costs, such as installation, should decrease with the experience gained and development of best practices (PEARCE, 2011).

Pearce also noted that the lifetime of photovoltaic panels, even on older models, has been showing itself to be greater than the 21-25 years usually guaranteed by the manufacturers, approaching 30 years or more. And yet, more than 65% of the panels in the market have an annual degradation rate of less than 1% (loss of productivity), used in most forecasts, reaching between 0.2 - 0.5% considering the technological advances, effectively extending the lifetime of the investment with quality generation.

Finally, we conclude that the expansion of solar and wind energy projects in Brazil is not only viable, but also a competitive option in relation to other sources of energy, both renewable and nonrenewable. For comparison, on April 20, 2010, the hydroelectric Belo Monte was auctioned at a sale price of R$ 77.97 per MWh, but with an effective selling price of R$ 90.58 per MWh (due to the allocation of a portion of the production to consortium and the free market with higher prices).

With the government support, especially in the creation of special credit lines (such as ABC – Low Carbon Agriculture) and long-term financing for large projects (through the BNDES), there are great options for implementing future wind and solar energy projects in the country.

3.2 Introduction in the production chain of biofuels:

The predominant energy sources in the Brazilian agricultural sector are: mineral diesel (57.3%), firewood (24.7%) and electricity (17.6%, predominantly generated from hydropower) (NATIONAL ENERGY BALANCE, 2012). Here we will initially address the scenario promoted by PNPB, which prioritizes the family farm and the castor bean crop.

In the production chain of biofuels, electrical energy is used in two main phases, depending on the type of biofuel and raw material used: the agrarian phase, mainly in pumping water for irrigation, and the industrial phase, the plants themselves (which can be fueled by bagasse cogeneration). The castor bean plantation, which is resistant to drought, is done without the use of irrigation, turning the electrification of rural property into a disadvantageous investment.

The extraction of oils from raw materials can be made by the farmer, as a way to increase the value of their product, by an intermediary or by the refineries themselves (integrated industrial unit). Although oil extraction in the rural property itself provides logistical gains (easy storage and transportation of the product direct to the factory, and the castor bean cake, used as fertilizer, is already on the farm), this is not the trend. There is an integration process between the extraction units and the biodiesel processing units, while the farmer provides only *in natura* raw material (GARCIA, 2007).

Garcia sees two trends in the biodiesel production chain in the Northeast: the concentration of industrial processes mentioned above, and the adoption of a main raw material, which is not the castor bean. The family farm model advocated by PNPB is mainly characterized by territorial dispersion, low mechanization and technical knowledge, small property and, hence, small scale production (GARCIA, 2007). This is hindering the ability of these farmers to meet the demand for vegetable oils for biodiesel production, as well as their own insertion in this production system, which now uses soybean oil as raw material, exported by Brazil and already inserted in the agribusiness of the Central-West region.

Although the organization of these producers in cooperatives can help to achieve a higher level of productivity and facilitate investments, unless the farmer-industry relationship and/or the raw materials focus of PNPB changes (such as sunflower, which has high oil content and needs irrigation), there is no justification for an investment in rural electrification of this order, especially if it is necessary to bear the high costs of the expansion of transmission lines. Otherwise, the installation of wind turbines and solar panels is one of the best solutions for the supply of electricity in areas that are remote and have a wide geographic dispersion of population (CABRAL, 2012).

Garcia believes that PNPB has not been successful in its mission to promote the integration of the farmer to the biodiesel production chain, as in other industries in the South and Southeast. In order to ensure the PNPB objective of social development and to prevent that biodiesel follows the same model of agribusiness for sugarcane alcohol, Garcia recommends promoting the production for the regional autoconsumption instead of marketing nationally, as well as authorizing direct marketing for small producers linked to family farms (GARCIA, 2007).

Below we have listed the major oilseed crops in Brazil, according to the region where they are best suited and whose production is more efficient.

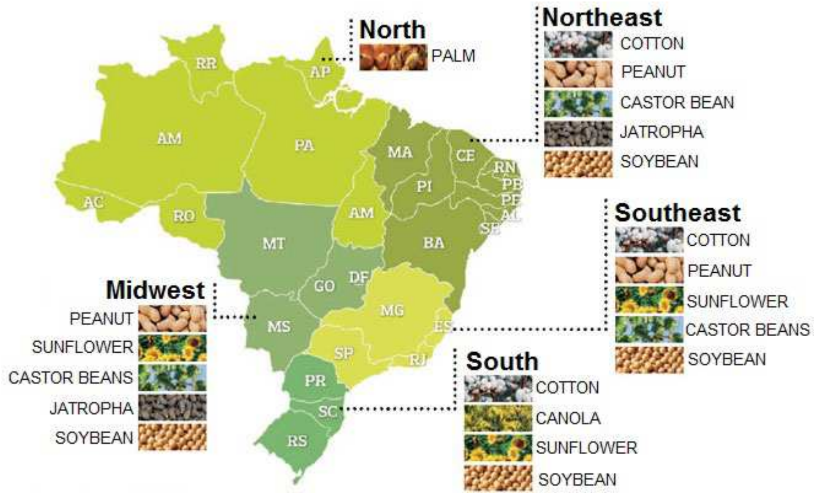

Figure 2. Major oilseed crops in Brazil divided by region.
Source: Globo Rural Magazine. Issue September/2010.

4. Introducing renewable energies in the biodiesel production inputs:

This item shows the productive context of the so called "clean energy" that, in Brazil, has been used as factors to improve the conditions of implementation of regional development policies.

The dependence of the global energy matrix on oil is seen today as a weakness by most governments, because of the geopolitical instability of this commodity, the perspective of its relative scarcity and the relation between fossil fuels and climate change. Increasingly efforts are made on expanding renewable energies, especially in technological improvements to achieve economic viability. Biomass and biofuels are presented as a strong solution for developing countries with a strong agricultural sector in the replacement of fossil fuels and firewood for export or domestic consumption.

The central question that drives this paper is that, in agricultural production, clean energies are not always used because of the affordable price of diesel or firewood. This can be reversed through policies that stimulate the introduction of wind and solar energy in strategic areas so as to economically enable the production of agricultural inputs, making the process even “cleaner” from the point of view of the supply chain as a whole.

Table 3. Advantages of the use of renewable solar and wind energies.

	Advantages
Renewable Energy	Can be considered as inexhaustible for the human scale compared to fossil fuels; • Smaller environmental impact than that caused by sources of energy derived from fossil fuels (coal, oil and gas), as it does not produce carbon dioxide and other greenhouse gases; • Less risky than nuclear power; • Allows the creation of new jobs (investment in disadvantaged areas); • Reduces CO_2 emissions, improves quality of life (cleaner air); • Reduces energy dependence on fossil fuels; • Gives energy independence to a country, since its use is not dependent on imported fossil fuels; • Conducts research into new technologies for better energy efficiency.
Wind Energy	• Inexhaustible; • Does not emit greenhouse gases or generate waste; • Decreases the emission of greenhouse gases (GHG). • Wind farms are compatible with other uses and land uses such as agriculture and livestock; • Job creation; • Generates investment in disadvantaged areas; • Financial benefits (owners). • Reduce the high dependence on foreign energy, particularly the dependence on fossil fuels; • Savings due to reduced acquisition of CO_2 emission rights to fulfill the Kyoto Protocol and EU directives and lower penalties for non-compliance; Possible contribution of GHG quota to other sectors of economic activity; • One of the cheapest sources of energy and can compete in terms of profitability with traditional energy sources. • Wind turbines require no fuel and require little maintenance, since they are only reviewed every six months; • Excellent return on investment. In less than six months, the turbine recovers the energy spent on its manufacture, installation and maintenance.

Solar Energy	• Solar energy does not pollute during its use. The pollution caused by the manufacturing of equipment for the construction of solar panels is fully controllable using the forms of control that currently exist; • The plants require minimal maintenance; • Solar panels are becoming increasingly powerful, while their cost are decreasing. This increasingly turns solar energy into an economically viable solution; • Solar energy is great in areas that are remote or difficult to access, since its installation in small scale does not require huge investments in transmission lines; • In tropical countries, like Brazil, the use of solar energy is feasible in virtually all the territory, and, in places far from the centers of production energy, its use helps reduce energy demand and consequently the energy losses that would occur in the transmission .

Source: Authors elaboration.

It is clear that the lack of these stimuli directly affect the results of the national industry. Private investment in renewable energy in Brazil grew by 8% in 2011, jumping to US$ 7 billion, driven mainly by the potential of wind energy. Worldwide, investment in renewable energy reached US$ 237 billion in 2011, surpassing the US$ 223 billion spent in the same year for the construction of new fossil fuel power plants.

The following figure shows the evolution of energy consumption in the agricultural sector, highlighting the gradual increase of the participation of electricity.

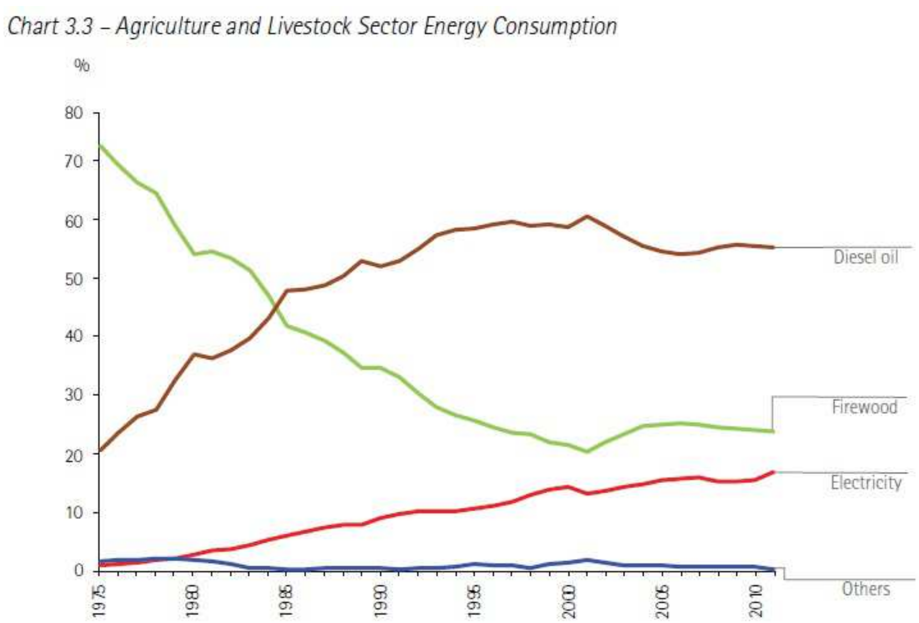

Figure 3 – Evolution of the structure of the energy consumption of the agricultural sector.

Source: National Energy Balance (2012, p. 77).

5. Conclusions

The potential for solar and wind energy in Brazil has been overlooked in public policies of the energy sector, according to the evaluation of a group of non-governmental organizations accompanying the sector. Studies show that, in the case of wind power, the untapped potential reaches 300 gigawatts (GW), which would amount to nearly three times the total installed capacity in the country currently.

The absence of a policy of incentives for technological innovation and expansion of the scale of energy production has hampered the expansion of other electrical potentials in the country, given the potential supply of clean energy that these systems offer.

In view of the existing national biodiesel production bottlenecks and PNPB's failure to address its own social goals, we suggest that the program be rethinked towards promoting the production of a wider range of oil seeds, according to the specificities and potential of each region. The castor bean, even with its high oil content, doesn't show good yield, results in a low quality biodiesel and it's not integrated into the existing biodiesel production chain. This restriction only further marginalizes the family farmer, that already has difficulty adapting to good farming practices, from the agribusiness wealth.

We also suggest contemplating fiscal benefits to cooperative production that happens alongside oil extraction activities. This way, the family farmer can aggregate value to his product while still being economic competitive, due to the ever lowering costs and increasing productivity of solar and wind energy.

The northeastern semi-arid holds enormous untapped solar and wind energy potential. It also constitutes the best solution for the mechanization of the family agriculture and extraction model, since the costs of installing new transmission lines from hydroelectric and thermoelectric power plants to a wide range of spread-out farmers would be not viable.

The PNPB is about to complete 10 years of existence but it hasn't showed much result in comparison to the private-lead sugar cane ethanol advancements of the past decade. Perhaps it is time to reevaluate the goals and policies of the program, taking into consideration how the biodiesel supply chain has been structuring itself and the advancements the Northeast has been making as an increasingly important power supplier. In this paper we suggested and justified the importance of state action in promoting a potent joint policy of renewable energy production and renewable energy incentives. Alongside proper country-wide bottleneck management, this could raise even further investments in clean energy production in the Northeast and make the family farmer a fundamental piece of the biodiesel supply chain, promoting sustainable development in the region.

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